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Systematic Studies of Bornean Zingiberaceae VI. Three New Species of *Boesenbergia* (Zingiberaceae)

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Three new species of the genus *Boesenbergia* (Zingiberaceae) from Borneo, *B. imbakensis*, *B. laevivaginata* and *B. subulata* are described. A revised key to the Bornean species of *Boesenbergia* is also provided.

Keywords: Borneo, *Boesenbergia imbakensis*, *Boesenbergia laevivaginata*, *Boesenbergia subulata*, Zingiberoideae

Boesenbergia Kuntze is one of the largest genera in the Zingiberaceae, currently including about 80 species. Since Smith's review of *Boesenbergia* in Borneo (1987) including 19 species, ten species have been described by Poulsen (1993), Cowley (1998, 2000) and Sakai & Nagamasu (2006b). Important characteristics to distinguish species include the arrangement of flowers on inflorescences (Sakai & Nagamasu 2006a) and anther dehiscence patterns (Valeton 1918, Smith 1987). By contrast to species in the seasonal tropics of Indochina which have distichous inflorescences and anthers dehiscing by slits, the majority of Bornean species have inflorescences of flowers arranged in one-sided spirals, and half of the one-sided spiral species have anthers dehiscing by pores (Sakai & Nagamasu 2006a). These characteristics are often difficult to observe in dry materials, however, since the inflorescences are usually concealed in leaf sheaths and bracts, and the flowers are relatively small and fragile.

A recent increase of good herbarium materials make the description of new species and study of poorly known species possible. In this paper, we describe three new species, and provide a revised key to Bornean *Boesenbergia*.

1. **Boesenbergia imbakensis** S. Sakai & Nagam., **sp. nov.** (Figs. 1, 2)

Haec species *B. burttianae* caulibus multifoliatis antherae thecae rimis dehiscentibus similis, sed laminis polis lanceolatis quam linearibus et foliis non flabellatis dispositis differt.

Typus. MALAYSIA. Sabah, from Camp E (Imbak Scientific Expedition Base Camp) upstream, Imbak Canyon, Kinabatangan, ca. 160 m alt., lowland tropical forest, 05°06.829′N, 116°57.605′E, petals white, staminode white, labellum white with yellow central line and a red blotch at the base, *Nagamasu 7235* (holo- KYO; iso- SAN).

Herbaceous plant up to 30 cm tall, fertile shoot ca. 4-leaved; bladeless sheaths 0–2, papery, much shorter than sheaths with lamina; leaf sheaths papery, glabrous, margin membranous; lamina 11–16 by 3–4 cm, lanceolate to oblanceolate, plain green, glabrous on both surfaces; apex slightly acuminate; petiole 4–7.5 cm, glabrous; ligule membranous, glabrous, ca. 1 cm long, entire, triangular. *Inflorescence* terminal, with 4–7 flowers arranged in one-sided spiral; outermost sterile bract 4–6 by ca. 1.3 cm, coriaceous, oblong, glabrous on both surfaces, apex acuminate; fertile bract ca. 26 by 4 mm, linear-lanceolate, membranous, glabrous on both surfaces; bracteole ca. 22 by 5 mm, lanceolate, glabrous on both surfaces, membranous, apex shallowly 2-lobed.

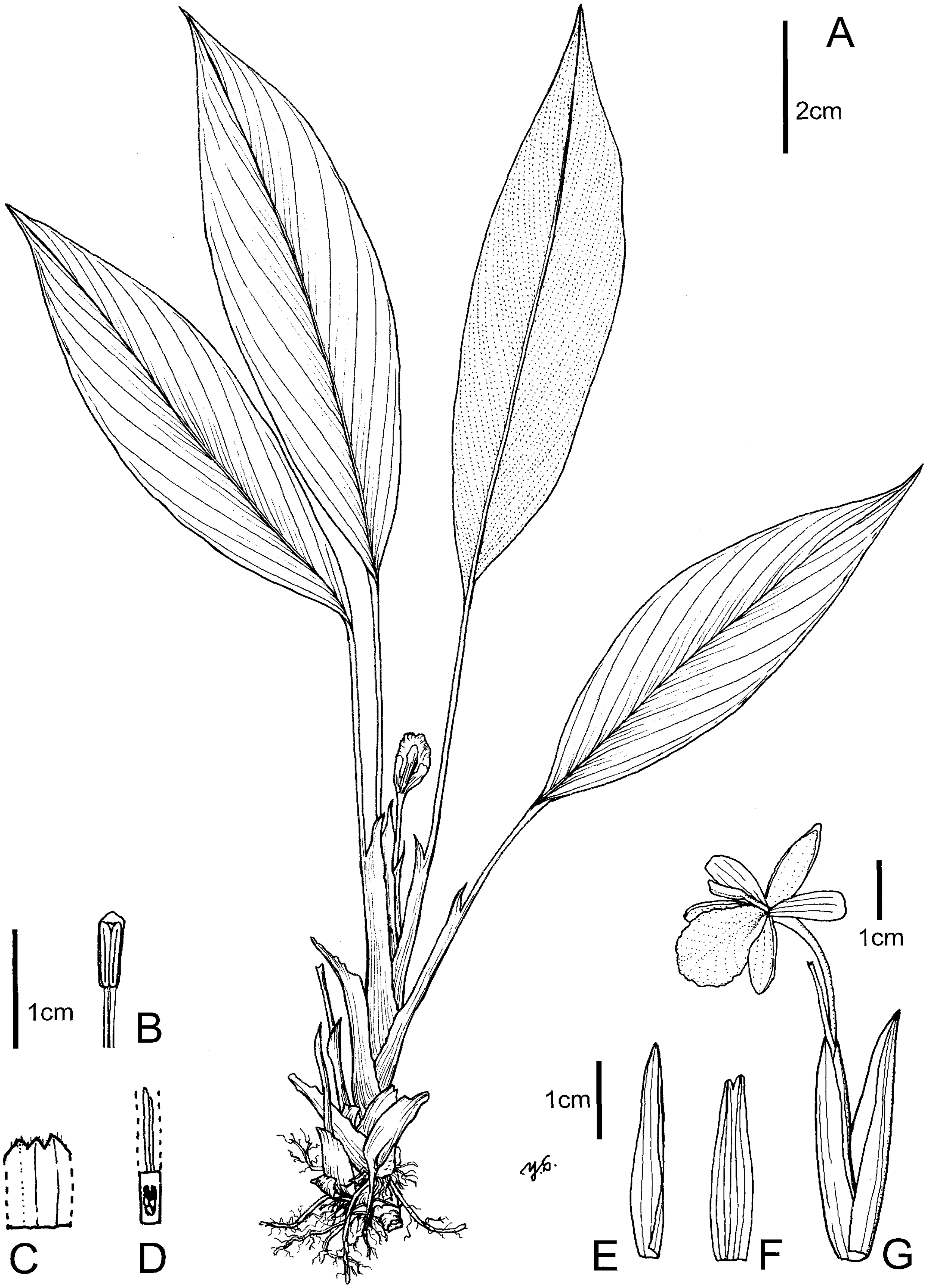

FIG. 1. *Boesenbergia imbakensis* S. Sakai & Nagam. A: habit. B: anther and stigma. C: calyx. D: epigynous glands and ovary. E: fertile bract. F: bracteole. G: inflorescence and flower (A: from dry material of *Nagamasu 7235*. B–G: from spirit material of *Nagamasu 7235*).

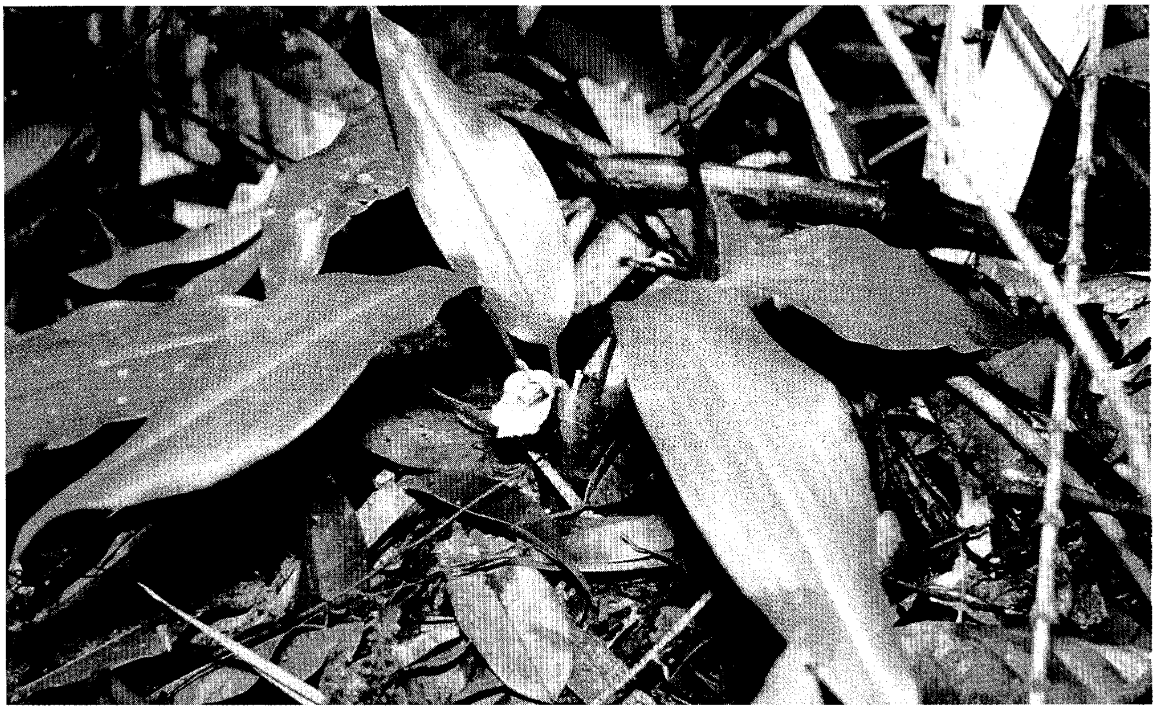

FIG. 2. Habit of *Boesenbergia imbakensis* S. Sakai & Nagam. (*Nagamasu 7235*).

Flowers borne singly, ca. 7 cm long, white; calyx ca. 7 mm long, tubular, membranous, glabrous on both surfaces, apex unequally and shallowly 3-lobed, ciliate; corolla tube ca. 4 cm long, almost glabrous outside, glabrous inside except for hairs on uppermost part; corolla lobes membranous, oblong, glabrous; dorsal lobe ca. 17 by 6 mm, laterals ca. 15 by 4 mm; lateral staminodes ca. 14 by 4 mm, elliptic, glabrous on both surfaces; labellum ca. 18 by 14 mm, oblong, white with yellow on the centre and red at the throat, glabrous; stamen ca. 12 mm long, filament ca. 6 mm long, shortly pubescent on the dorsal surface, glabrous on the ventral; anther ca. 5 mm long, thecae opening by slits, glabrous; anther crest ca. 1 mm, glabrous, entire or slightly obtuse; ovary ca. 4 mm high, unilocular with ca. 6 ovules, glabrous; epigynous gland ca. 7 mm, in two parts, linear. *Capsules* unknown.

Other specimen examined. MALAYSIA. **Sabah.** From Camp E (Imbak Scientific Expedition Base Camp) upstream, Imbak Canyon, Kinabatangan, ca. 160 m alt., lowland tropical forest, 05°06.829′N, 116°57.605′E, petals white, staminode white, labellum white with yellow central line and a red blotch at the base, *Nagamasu 7232* (KYO).

Note. Vegetatively, this species is similar to *Boesenbergia parva* (Ridl.) Merr. in the several-leaved shoot, and lanceolate, relatively small lamina with distinctive petiole. However, it is a more glabrous plant with anthers dehiscing by slits and may not be closely allied to *B. parva.*

2. **Boesenbergia laevivaginata** S. Sakai & Nagam., **sp. nov.** (Fig. 3)

Haec species *B. stenophyllae* R. M. Sm. caulibus multifoliolatis foliis angustis longipetiolatis basi uneaqualibus antherae thecae poris dehiscentibus valde similis, sed labello minore ca. 1.3 cm longo (ca. 2.5 cm longo in *B. stenophylla*) et vaginae foliorum laevibus striatis in foliis supremis conspicue latae factae differt.

Typus. MALAYSIA. Sarawak, 4th Div., Marudi Dist., Bario, top of ridge near Batu Buli, 4500–8000 ft., shaded under old closed forest, sandstone soils, *Lamb AL SAR 231/85* (holo- E).

Erect herb ca. 20–50 cm tall, fertile shoot 4–9 leaved; bladelss sheaths usually absent; lamina 11–17 by 2–4 cm, papery, elliptic to oblanceolate, glabrous except around the midrib on the lower surface, dull green on the upper surface, sometimes paler along midrib, reddish brown on the lower in the dried condition, upper surface dark green, lower

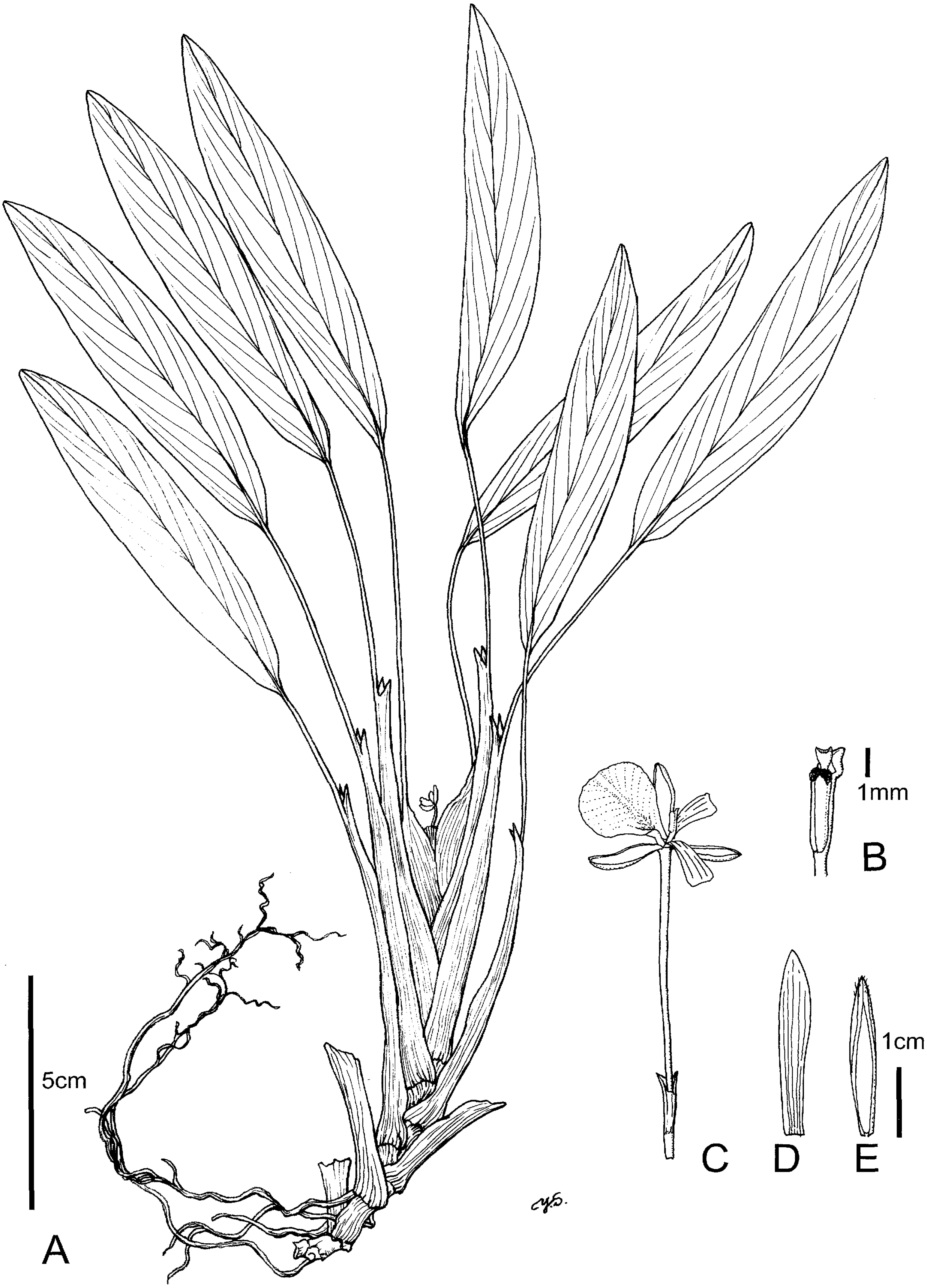

FIG. 3. *Boesenbergia laevivaginata* S. Sakai & Nagam. A: habit. B: anther and stigma. C: flower. D: bract. E: bracteole. (A, B: from dry material of *Lamb AL SAR 231/85*. C: composite from dry materials of *Lamb AL SAR 231/85* and *Aninjuh Surat SAN 143428*. D, E: from dry material of *Argent 25108510*).

surface of (new) leaves reddish or purplish when alive (according to the notes on some specimens cited below), apex acute, ciliate, base unequally cuneate; petiole 5–13 cm long, glabrous; sheath 6–12 cm long, papery, striate and shiny, yellowish brown, often sparsely hairy on the margin, otherwise glabrous, margin membranous; ligule up to 6 mm, bilobed to the base, glabrous to sparsely hairy. *Inflorescence* terminal, embraced between innermost leaf sheaths, which are broader and shorter and with smaller ligules than outer ones; number of flowers many, congested and concealed in leaf sheaths; bract ca. 27 by 4 mm, membranous, oblong, glabrous; bracteole ca. 23 by 4 mm, elliptic, membranous, glabrous, apex ciliate. *Flowers* white, ca. 6 cm long, glabrous except for dense hairs at the throat and sparse hairs on the centre of the upper surface of the labellum; tubular part of the corolla ca. 4.5 cm; corolla lobes membranous, elliptic, ca. 10 by 3 mm, glabrous on both surfaces; labellum ca. 13 by 10 mm, oblanceolate, white with yellow line on the centre; lateral staminodes 8 by 3 mm; stamen 5 mm, glabrous; anther ca. 3.5 mm, thecae dehiscing by pores; anther crest ca. 1 mm, entire; stigma cup shaped, dorsal opening ciliate; ovary ca. 4 mm high, glabrous; epigynous gland unknown. *Fruit* unknown.

Other specimens examined. MALAYSIA. **Sarawak.** Belaga Dist.: Batang Balui, Batu Laga Plateau, Ulu Sg. Elyak, terrestrial ginger, 20–30 cm tall, petioles green, reddish at the leaf base, leaves green above, reddish on the lower surface, flowers terminal, white, yellow at the lip, vernacular name: jerangau merah, *Yii Puan Ching S56724* (E, SAR). —Tatau Dist.: Tatau, Vicinity of Minah Camp (timber camp of L.L.B.T.C.), along Sg. Kakus, 50–80 m a.s.l., *M. Hotta 15816* (KYO). —Marudi Dist.: Kelabit Highlands, stunted primary forest behind Ramudu, dominating herb on open forest floor, rhizomes and buds yellow/beige-orange, underside of new leaves reddish, rhizome with aromatic smell, vernacular name in Malay: jeringau merah, *H. Christensen 250* (K); *ibidem*, Pa Dali, secondary forest, 1100 m a.s.l., terrestrial ginger on litter soil, 25–35 cm tall, runners reddish, bracts greenish red, flowers white, *Yii Puan Ching S56240* (SAR); *ibidem*, Apad Runan, Pa Di-it water fall, submontane forest, 1550 m a.s.l., sterile collection, terrestrial gingers, 20–30 cm tall, rhizome reddish above the litters, petioles reddish to dark green toward leaf-blades, leaves green above, whitish to pale red on the lower surfaces, vernacular name: jerangau merah, *Yii Puan Ching S56238* (SAR); *ibidem*, Apad Keruma, submontane mossy forest, 1450 m a.s.l., terrestrial ginger, 30–40 cm tall, leaves reddish to whitish on lower surfaces, flowers white, *Yii Puan Ching S55914* (SAR); *ibidem*, sterile collection, name in Malay: jerango merah, *Wong S30449* (SAR); Bario, Route to Bt. Lawi, 1190 m a.s.l., terrestrial herb, pedicel, sepal and petal white, lip white tinged yellow, *Dyg. Awa & Bernard Lee S50603* (E, K, SAR); *ibidem*, Sg. Lokoh, Ramudu, *Rena George et al. S57090* (K); *ibidem*, Arur Bilit, Pa Umor, kerangas forest, vernacular name: keburo apat (Kelabit), jerangau merah, *Rena George et al. S57024* (K); *ibidem*, Arur Bilit, near Pa Umur, bottom of hillside, kerangas, 1000 m a.s.l. at least, flower white with yellow spot on lip, stigma and column white, bract enclosing inflorescence is filled with mucilage, *Pearce 634* (E); *ibidem*, 1.5 km straight W of Arur Dalan, ridge above Arur Lab Valley, 3°45′N, 115°26′E, alt. 1200 m, terrestrial herb about 0.5 m, leaves dark green, reddish below, vernacular name in Kelabit: kaburi apad (apad = hill), *Poulsen 1867* (SAR). —Limbang Dist.: watershed of Sg. Buda, kerangas forest, sandy loam soil (kerapa type), herb, 0.25 m tall, dark green and pinkish stem and dark green leave with pinkish leaf at lower surface, vernacular name: jerangau merah, *Logie et al. S86548* (SAR); away from Long Raya to Sg. Adang, 1100 m a.s.l., herb in large cluster, 20 cm tall, stem green to reddish, petiole, leaves green, peduncles, sepal, petals white, lips yellow, *Julaihi et al. S77260* (SAR). **Sabah.** Sipitang Dist.: Lower Sg. Maga, 1200 ft a.s.l., lower montane oak-chestnut forest & riverine forest, herb, flowers white with pale yellow, *Aninjuh Surat SAN143428* (K); Long Pa Sia, ca. 5°26′N 155°44′E, in shade of submontane forest, 1000 m a.s.l., plant to 30 cm, leaves glossy dark green above, purplish beneath, inflorescence not really emerging from the leaf sheaths, flowers white with translucent lines, *G. Argent 25108510* (E); Ulu Padas, ca. 3 km E of Long Pasia, ridge, open forest, terrestrial herb to 0.5 m, often dominating in clumps, lamina dark green shiny, petiolate 20 cm, bracts purple, flowers white with central yellow, bifid bar, vernacular name in Lundayeh: keri buro, *A. D. Poulsen 1792* (E).

Notes. When Smith (1987: 230) described *Boesenbergia stenophylla* R.M. Sm., she recognized two specimens from Bario district in Sarawak that "closely approach *B. stenophylla* but differ in the shining striate leaf sheaths and (probably) more numerously flowered inflorescence." We have found additional specimens of the taxon, which share distinctive characteristics such as a reddish brown colour on the lower surfaces of the leaves, long petioles, shining striate leaf sheath and elliptic shape of lamina, from Bario and other regions. The structure of the inflorescence

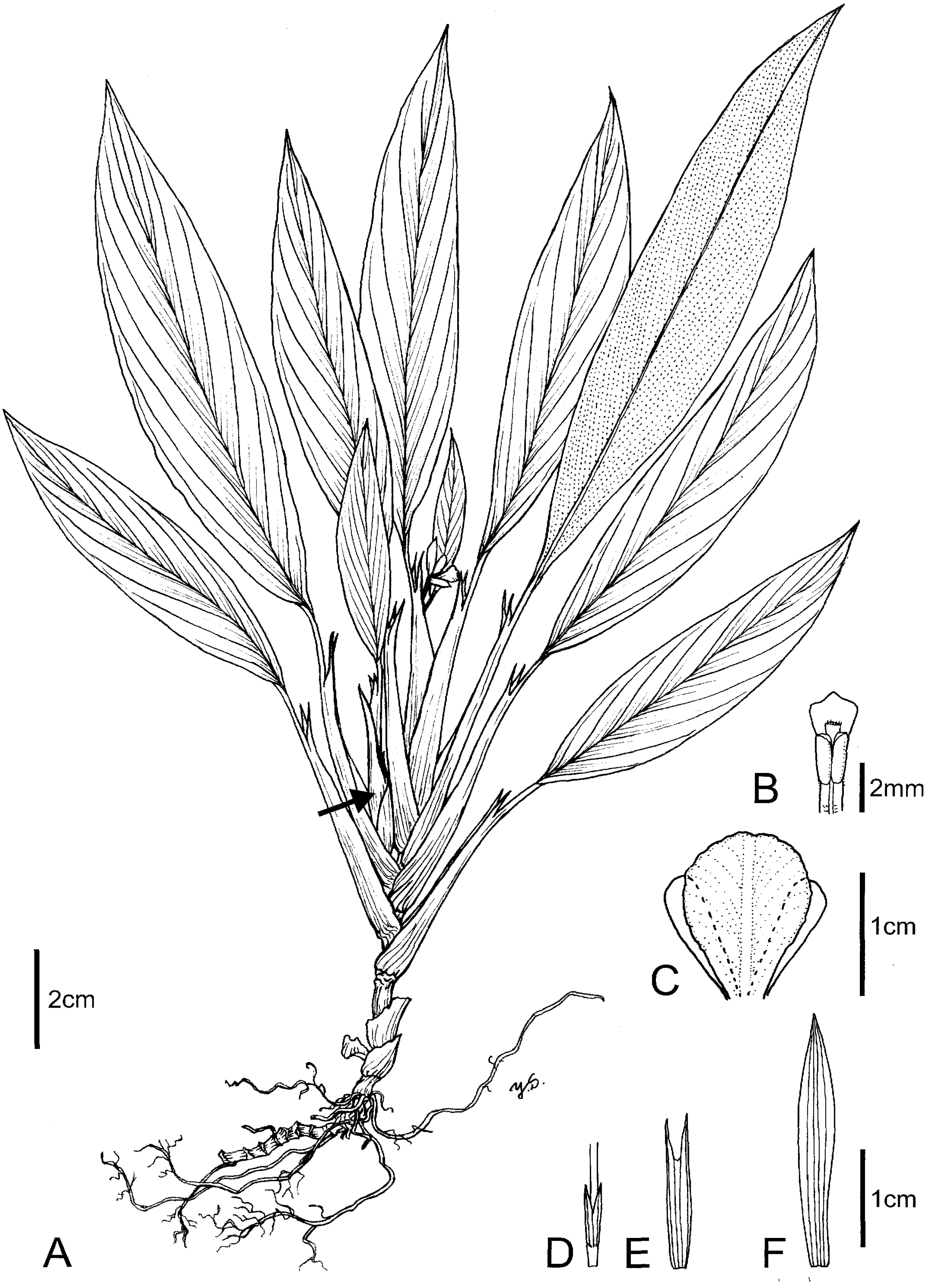

FIG. 4. *Boesenbergia subulata* S. Sakai & Nagam. A: habit, mature shoot bearing a young shoot at the axil of a leaf on the left (arrow). B: anther. C: labellum and lateral corolla lobes. D: calyx. E: bracteole. F: bract. (A, B, C: from dry material of *Kirkup D. W. 818A*. D, E, F: from dry material of *M. Hotta 12350*).

which is completely concealed in the leaf sheaths could not be examined, but probably of a one-sided spiral as in many other *Boesenbergia* species from Borneo, as the inflorescence has numerous flowers congested on a very short rachis. The conspicuously thickened innermost leaf sheaths may contain water or mucilage to protect the inflorescence.

The holotype of *Boesenbergia stenophylla* at E, which were originally collected at Long Pasia, consists of a spirit collection only (M. Newman, personal communication). However, the drawings of dissected flowers of *B. stenophylla* in Smith (1987) are based on the type material, *Argent* 18/85 (E) and they are different from the new taxon in their larger anther crest and longer filament, characteristics also observed in *Burtt & Woods B2107* (E) cited as *B. stenophylla* by Smith (1987). The two species may occur sympatrically.

Boesenbergia laevivaginata seems to occur forests in high altitudes, although there is a specimen from Sg. Kakus, 50–80 m a.s.l. (*M. Hotta 15816*).

3. **Boesenbergia subulata** S. Sakai & Nagam., **sp. nov.** (Fig. 4)

Haec species *B. oligospermae* (K. Schum.) R. M. Sm. laminis minoribus lanceolatis plus minusve glabris et antherae thecae poris dehiscentibus valde similis, sed floribus albis minoribusque et antherae pilis glanduliferibus absentibus differt.

Typus. BRUNEI. Belait, Labi, herb, flowers erect, long-tubular, originating from within reddish leaf sheaths with yellow-brown warts, petals white with translucent veins and yellow labellum, *Kirkup D. W. 818A* (holo- K).

Erect herb ca. 20 cm tall, 2–8 leaved; bladeless sheaths 0–2, probably lost in older shoots; lower leaves occasionally have young shoots in axils; lamina (6–)7–13(–15) by 1.3–2.8 cm, papery, lanceolate, glabrous or slightly hairy on both surfaces; apex acute, base cuneate to slightly attenuate; petiole 7–25 mm long, glabrous; sheath (3–)4–5.5 cm long, papery, striate, glabrous or rarely hairy on the margin, otherwise glabrous, margin membranous; ligule 4–13 mm long, papery, 2-lobed, triangular, glabrous. *Inflorescence* terminal, with ca.7 flowers arranged in a one-sided spiral; bract ca. 31 by 3.5 mm, membranous, linear-oblanceolate, totally glabrous; bracteole ca. 15 mm long, membranous, open to the base, 2-toothed, totally glabrous. *Flowers* white, calyx ca. 6 mm long, membranous, tubular, 2-toothed, glabrous; corolla tube glabrous; corolla lobes membranous, ca. 8 mm long, glabrous on both surfaces; labellum ca. 10 mm long, obovate, glabrous except for long hairs at the throat of the corolla tube, white with some yellow on the centre, possibly some orange-red colour at the very base; lateral staminodes ca. 8 mm long, oblong to obovate, glabrous; stamen ca. 5 mm long, anther ca. 2.5 mm, thecae dehiscing by pores, anther crest ca. 1.5 mm, shallowly 3-lobed; filament ca. 1 mm, with long hairs at the base and some very short hairs on near base of the thecae on the filament; stigma cup-shaped with apical-opening, with sparsely hairy around the opening; ovary ca. 2 mm long, glabrous; epigynous glands unknown. *Capsules* unknown.

Other specimens examined. BRUNEI. **Temburong.** Amo, Ulu Belalong: herbaceous ca. 30 cm tall, leaves alternate, sheath winged half-way the petiole, flower solitary, terminal, whitish including pedicel, lower petals large with yellowish tinge in the middle, *BRUN15897* (K); small herb 10 cm high, flower with long tube sheathed by the leaf stalks, corolla white apart from yellow labellum, orange-red at the very base, *Kirkup D. W. 859* (K). **Belait.** Seria, Teraja forest reserve, en route from Kpg. Mendaram to Bt. Teraja, 100–250 m a.s.l., *M. Hotta 12693* (KYO); Bukit Puan, in primary forest near government saw-mill, *M. Hotta 12350* (KYO).

MALAYSIA. **Sarawak.** 4th Div.: Mulu, Along Sungai Melinau-paku, foot of Gunung Mulu, alt. 50–100 m, *M. Hotta 15224* (KYO).

Note. Vegetatively, this species is characterized by relatively thick leaf sheaths and ligules bilobed to the base. The characters are probably lacking in *Boesenbergia oligosperma* (K. Schum.) R. M. Sm., which may be most closely related to the new species. The other interesting characteristic is the production of new shoots in the axil of fertile leaves. It has rarely been observed in other *Boesenbergia*. The distribution of the species is limited to Brunei except for one specimen from Gunung Mulu, Sarawak.

Revised Key to Bornean *Boesenbergia*
(modified from Sakai & Nagamasu, 2006b)

1a. Creeping herbs; shoots normally single-leaved; inflorescence more or less sessile; anther dehiscing by slits 2
b. Erect herbs; shoots with one to many leaves; inflorescence sessile or long pedunculate; anther dehiscing by slits or pores 6
2a. Leaves more or less circular, obtuse or obscurely emarginate at apex .... *B. orbiculata* R. M. Sm.
b. Leaves elliptic or lanceolate, acute at apex 3
3a. Leaves plain green 4
b. Leaves variegated 5
4a. Corolla tube pubescent outside; flowers not red at throat; labellum entire .... *B. flavoalba* R. M. Sm.
b. Corolla tube glabrous outside; flowers red at throat; labellum bilobed .... *B. flavorubra* R. M. Sm.
5a. Petioles to 0.5 cm; lamina 4–8 by 1.5–2 cm, mid green with a broad silver band on either side of the midrib above .... *B. kerbyi* R. M. Sm.
b. Petioles 2–3 cm; lamina 7–12 by 2.5–7 cm, dark green with a band of lighter green up the midrib, variegation sometimes extending to the main lateral veins .... *B. variegata* R. M. Sm.
6a. Fertile shoots single-leaved, rarely bladeless or 2- or 3-leaved 7
b. Fertile shoots with two or more leaves 11
7a. Lamina 50 by 12 cm or larger .... *B. grandifolia* (Valeton) Merr.
b. Lamina much smaller, not exceeding 30 cm long 8
8a. Lamina deeply cordate at the base .... *B. cordata* R. M. Sm.
b. Base of the lamina more or less attenuate not cordate 9
9a. Petiole 17–34 cm long .... *B. bruneiana* Cowley
b. Petiole not exceeding 17 cm 10
10a. Lamina 7–12 cm wide; petiole robust ca. 5 mm thick; lamina with appressed hairs especially around midrib below .... *B. lambirensis* S. Sakai & Nagam.
b. Lamina less than 7 cm wide; petiole slender, 2 mm or less thick; leaves glabrous .... *B. ischnosiphon* S. Sakai & Nagam.
11a. Outermost bract forming a bucket or vase-like structure enclosing inflorescence sometimes together with sheaths of upper leaves; lamina large, much longer than 30 cm 12
b. Leaf base or sheaths not thickened as above, or if thickened, leaves are much shorter 14
12a. Petiole 42–50 cm long .... *B. jangarunii* Cowley
b. Leaf base long-attenuate forming a winged petiole less than 25 cm long 13
13a. Inflorescence densely pubescent; anther ca. 3 mm long, dehiscing by subapical pores .... *B. hosensis* Cowley
b. Plant almost glabrous; anther ca. 10 mm long, dehiscing for ca. 6 mm long (probably dehiscing by slits) .... *B. armeniaca* Cowley
14a. Leaves larger than 20 by 7 cm; anthers dehiscing by pores 15
b. Leaves shorter than 20 cm, if longer narrower than 7 cm; anthers dehiscing by slits or pores 16
15a. Leaf sheath sparsely hairy or glabrous; bracts 5–8 cm; corolla tube 8–10 cm; ovary glabrous .... *B. grandis* R. M. Sm.
b. Leaf sheath densely hairy; bracts 2–3.5 cm long; corolla tube ca. 5.5 cm long; ovary densely hairy in upper half .... *B. lysichitoides* S. Sakai & Nagam.
16a. Inflorescence long exserted from the leaf sheaths when fully grown, spindle-shaped; flowers red and white .... *B. pulchella* (Ridl.) Merr.
b. Inflorescence never long exserted or spindle-shaped; flower colours various 17
17a. Leaves linear, arrangement of blades strongly flabellate 18
b. Leaves elliptic, lanceolate or, rarely linear-lanceolate, arrangement of blades never flabellate 19
18a. Flower plain yellow; anther dehiscing by apical pores; bracts 3.5–6.5 cm .... *B. flabellata* S. Sakai & Nagam.
b. Flower white, yellow in the centre, pink at the base; anther dehiscing by slits; bracts up to 3 cm .... *B. burttiana* R. M. Sm.
19a. Leaves variegated (variegation may be lost in dried material in *B. hirta*) 20
b. Leaves plain green 24

20a. Leaves bullate; dark green around main veins and almost silvery on raised area .... *B. hutchinsoniana* B. L. Burtt & R. M. Sm.
b. Leaves smooth with a silver, yellowish or light green central cloud 21
21a. Petiole never exceeding 3 cm; lamina oblanceolate with attenuate base .... *B. hirta* (Ridl.) Merr.
b. Petiole usually much longer than 3 cm; lamina lanceolate to elliptic with cuneate base 22
22a. Leaves with a silver cloud; flowers yellow, labellum orange spotted .... *B. ornata* (N. E. Br.) R. M. Sm.
b. Leaves with a yellowish cloud; flowers orange or white with some yellow and reddish purple 23
23a. Leaves 5–12 by 3–5 cm; flower orange, darker at base of labellum; anther dehiscing throughout its length .... *B. aurantiaca* R. M. Sm.
b. Leaves 18–23 by 4–6 cm; flower white with some yellow and reddish purple; anther dehiscing by apical pores, or anther dehiscent only in upper 2/3 .... *B. belalongensis* A. D. Poulsen
24a. At least a few uppermost leaf sheaths thickened and forming a cup-shaped structure 25
b. Leaf sheaths not thickened as above 26
25a. Innermost leaf sheaths enclosing inflorescence much shorter and wider than outer ones; leaves drying darkish-brown .... **B. laevivaginata** S. Sakai & Nagam.
b. All leaves with more or less equal laminae; leaves green or grey-green when dry .... *B. urceoligena* A. D. Poulsen
26a. Anther dehiscing by slits throughout their length .... **B. imbakensis** S. Sakai & Nagam.
b. Anther dehiscing by pores 27
27a. Lamina wider than 4 cm (need to be checked) .... *B. apiculata* (Valeton) Loes.
b. Width of lamina less than 4 cm 28
28a. Lamina narrowly lanceolate, 12–20 by 1.5–3 cm, petiole usually 7–8 cm .... *B. stenophylla* R. M. Sm.
b. Lamina much shorter, up to 12 cm long, if longer, petiole much shorter than 7 cm 29
29a. Leaf sheath and ligule long pubescent .... *B. parva* (Ridl.) Merr.
b. Leaf sheath and ligule almost glabrous 30
30a. Flowers yellow-orange .... *B. oligosperma* (K. Schum.) R. M. Sm.
b. Flowers white and yellow occasionally with red in throat .... **B. subulata** S. Sakai & Nagam.

Excluded species: *B. striata* (Valeton) Loes. for insufficient information.

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